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(NASA-TM-108069) THE WATER  
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by B. C. Wolverton

This remarkable plant can purify water and provide a renewable source of energy, feed, food and fertilizer

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The water hyacinth (*Eichhornia crassipes*) is the fastest growing plant known to man. Although once known only in South America, in Venezuela in particular, it has now been spread to approximately 50 countries around the globe. Its dispersion during the past century is due to an alluring structure consisting of a floating rosette of green leaves adorned by delicate white or lavender flowers. Sought for its beauty, the hyacinth was first introduced into the USA by the Japanese at the 1884 Cotton States Exposition in New Orleans, Louisiana, as souvenirs of that event. Beauty was soon overridden by problems, as hyacinths made their way into drainage canals, swamps, streams and bayous, hampering many waterways of the south-eastern USA. In its natural South American environment, insects and viruses help to regulate its explosive growth rate and thus minimize any adverse effects to the environment. In other parts of the world where man has introduced this plant, explosive growth rates have occurred in the absence of natural control vectors. Efforts to eradicate or, at least, to restrain its growth have been underway for some 80 years now, and thus far have been virtually unsuccessful. The water hyacinth persists with vigour in every region it has ever invaded.

I intend to show in this article the benefits that can be reaped from the highly prolific water hyacinth if put to work under controlled conditions. In essence, the water hyacinth has taken on a whole new image as a result of studies at the National Aeronautics and Space Administration's National Space Technology Laboratories (NSTL) in Mississippi, USA. It has been transformed from prolific pest to potential provider.

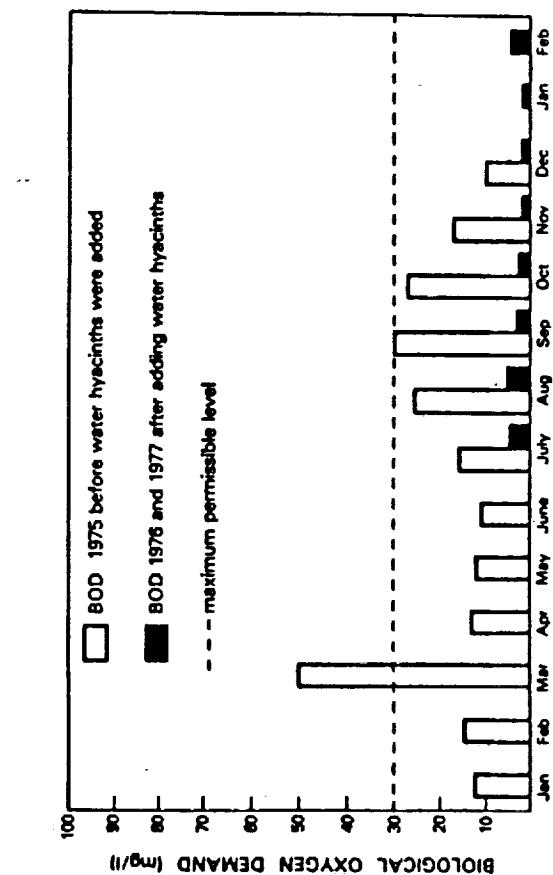


Water hyacinth sewage purification unit at  
NASA laboratories

#### 800 tonnes per hectare

The water hyacinth has pronounced, spongy, swollen petioles, or leafstalks, that allow it to float. In lone plants the base of each petiole is inflated with air sacs, forming a float with an internal structure similar to that of the foamed

plastic material used to make buoyant beach toys. The rosette of petioles creates a circle of floats that prevents the plant from capsizing. When the plants are crowded together, however, the petioles are less swollen, and grow tall and slender. In this way one hectare can be packed with 360 to 480 tonnes of water hyacinths. The white or lavender flowers, borne on a spike, rise from the centre of the plant. If the flowers are not pollinated by insects after being open for 48 hours, self-pollination takes place. For the next three weeks the tiny black seeds mature, and the flower spike bends downwards. The seeds are the only part of the water hyacinth with a specific gravity greater than one. They sink to the bottom mud where they can remain viable for years. These seeds can germinate only when an exact process of drying and rewetting has taken place.



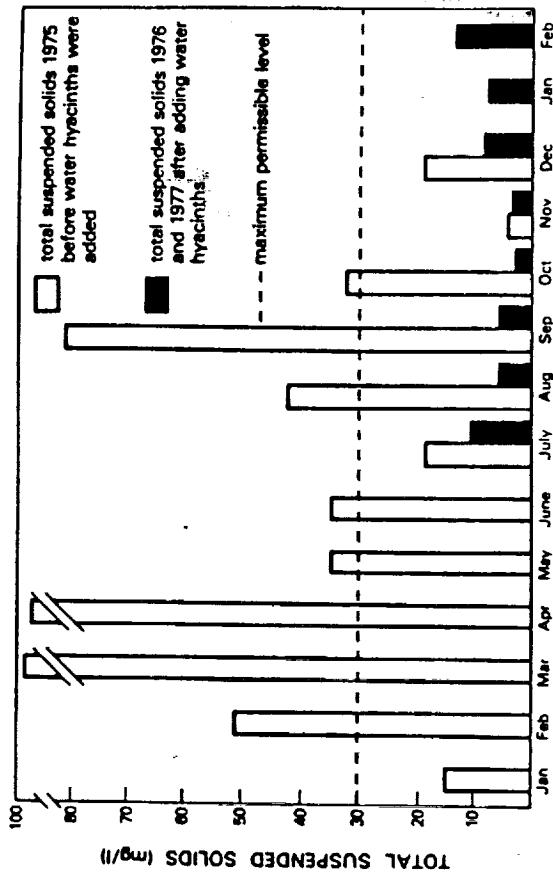
Therefore, the seeds are only a back-up reproductive system. The water hyacinth reproduces mainly in a vegetative, non-sexual manner by means of slender horizontal runners, called stolons, that are sent out across the surface of the water. As the stolon grows, new plants form at the tips and, in a matter of days, a parent is surrounded by offspring. Optimum water temperature for water hyacinth growth is 26-30°C. Under favourable conditions it can double its number every ten days. Frost may kill the plant's outer leaves, but unless the waterway freezes or stays near freezing for long periods, the vertical stem, or rhizome, remains viable and responds to returning warmth with new roots, leaves and stolons.

The water hyacinth can tolerate salt agricultural run-off, sewage or industrial

water for only very brief periods. Plants can tolerate 1.0 part per thousand (ppt) salinity for indefinite periods of time; whereas 2.2 ppt salinity is usually lethal after 30-day exposure periods.

#### A water purifier

Terrrestrial plants get their nutrients from minerals dissolved in the moisture of soil. The water hyacinth's roots hang into the water, allowing maximum and continuous contact with the water from which it extracts all of its nutritional requirements. The principal plant macronutrients are nitrogen, phosphorous and potassium, which are also the major elements of fertilizers. When these substances enter waterways as



effluent, they are considered pollutants and beyond recovery. The water hyacinth absorbs large quantities of these elements along with numerous other chemicals, and utilizes them in the metabolic process of producing new plant material or concentrates them in root and plant tissue. When the water hyacinth is systematically harvested so that successive crops continuously remove nutrients from the water, the plant becomes a natural pollution control agent. Studies undertaken thus far have proven it of a great value in purifying domestic and certain industrial waste waters. An example of the water hyacinth's ability to reduce the biochemical oxygen demand (BOD) and total suspended solids (TSS) of domestic waste water is shown above.

NASA has also been using duckweeds in conjunction with water hyacinths to treat all domestic waters at NSTL. Duckweeds (family Lemnaceae) are the simplest and smallest of the flowering plants, ranging in length from 1.5 cm to 0.1 mm. These small, free-floating, aquatic plants of the genera *Spirodela*, *Lemna* and *Wolffia* are normally found co-existing with water hyacinths. They can survive in low light intensities of 50 footcandles or less. When the frost kills the exposed vegetation of the water hyacinth, the cold tolerant species of duckweeds flourish and function as an effective waste water treatment plant. The frost-free season brings about the return of the more aggressive water hyacinth, suppressing the duckweed, causing it to take on a less

**Table 1 Protein From Water Hyacinths and Duckweeds (essential amino acids, g/100g crude protein)**

Code*	Iso-Proline	Lysine	Methionine	Phenylalanine	Threonine	Tyrosine	Tryptophane	Vaileine	Value
51.1	4.2	4.3	4.2	2.2	2.3	2.6	1.4	2.6	4.2
51.2	4.92	9.20	6.60	2.06	6.10	4.99	1.50	4.67	5.44
51.3	4.09	1.68	5.96	1.47	5.70	4.56	1.04	3.55	5.03
51.3	4.64	1.87	6.44	2.16	5.69	4.61	2.10	3.53	5.03

<sup>1</sup> Protein Extracted From Green Water Hyacinth Leaves  
<sup>2</sup> Protein From Dried Water Hyacinth Leaves  
<sup>3</sup> Protein From Dried Duckweeds (*Spirodela* and *Lemna* sp.)

\* Per cent of Dry Weight

waste and producing oxygen, food and pure water in a completely closed system in space stations is a biological and engineering challenge that will require many years to perfect, but the technology evolving from this project is having a major beneficial impact on immediate earthly problems.

#### Food, feed and fertilizer

During the period May to October 1977, growth rate studies conducted at NSTL utilizing water hyacinths grown in lagoons receiving raw sewage showed an average of 46 per cent weight increase per week. The growing season in south Mississippi also includes April for the Gulf Coast Region. Data was extrapolated for April. Over this seven month span, 3080 wet tonnes or 154 dry tonnes (based on an approximate solids content of 5 per cent of wet weight) per hectare were produced. Duckweeds can be expected to produce 30 per cent or more of this volume of biomass when grown under similar conditions. It is possible to maintain such a high growth rate because of high nutrient levels, warm temperatures (26-30°C), and increased carbon dioxide concentrations as a result of the anaerobic digestion taking place in the bottom portion of the lagoons.

The hyacinth's nuisance characteristics are being further abated as scientific investigations unveil its potential as a producer of such desirable products as high quality vegetable protein, vitamins, minerals, energy (in the form of biogas), fertilizer and chemicals. Along these lines, NASA is conducting research into the possible utilization of water hyacinths and other plants for life support functions in remote space stations. The use of water hyacinths and/or other higher plants for recycling human waste in the waste water treatment system investigated at NSTL which proved highly effective and efficient are now being put to use in parts of the USA by numerous cities and communities for waste water treatment. NASA has assisted with the design and/or operation of water hyacinth waste water treatment systems ranging from single dwellings to the cities of Coral Springs, Disney World, San Diego, and Rio Hondo, Texas. These systems are now either in operation,

under construction, or planned.

The results of various waste water treatment systems investigated at NSTL which proved highly effective and efficient are now being put to use in parts of the USA by numerous cities and communities for waste water treatment. NASA has assisted with the design and/or operation of water hyacinth waste water treatment systems ranging from single dwellings to the cities of Coral Springs, Disney World, San Diego, and Rio Hondo, Texas. These systems are now either in operation,

plants as corn, sorghum, peas, cucumbers, squash and tomatoes have been grown in abundance at NSTL using decomposing water hyacinths as the sole nutrient source. Some of the minerals found in water hyacinths and duckweeds grown in domestic sewage are shown in Table 2.

The hardness and high productivity of the water hyacinth can be put to use in a controlled, fresh water environment to remove pollutants and nutrients from domestic waste waters and return these minerals to the earth in a safe, stabilized form. In the process of absorbing nutrients and minerals from domestic sewage, the water hyacinth produces large quantities of plant biomass which can be useful for feed, fertilizer and energy.

#### The promise of aquaculture

At present, water hyacinth systems are limited to fresh water environments in warm climates. However the use of cold-tolerant duckweeds as a winter supplement shows promise for extending this waste water treatment method further north. Covered systems would still be required in extreme northern zones.

The use of vascular aquatic plants is a simple, economical method for waste water treatment. It can be applied in the design of small single home systems as well as used to design more complex systems treating tens of millions of litres of sewage a day. Aquaculture for waste water treatment is one of the most promising concepts to emerge recently for waste water treatment because it is simple and cost effective and converts undesirable pollutants into products such as energy, food, and fertilizer. □

**Table 2 Composition (Dry Weight) of Whole Plants From Domestic Sewage Lagoon**

Plant	Protein %	Fats %	Oils %	Po-	Na-	Kthal-	Nitro-	Par-
				min-	s-	gen-	gen-	ph-
Duckweed	35.5	34	1.00	2.00	0.50	0.17	0.15	0.25
Water hyacinth	24	22.0	1.50	4.00	0.40	1.74	0.25	